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Unified Nomenclature for Genes Involved in Prokaryotic Aerobic Arsenite Oxidation

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The first observation of bacterial oxidation of arsenite to arsenate was described in 1918 (5), but it was only in 1992 that the first arsenite oxidase was isolated (1). Arsenite oxidase from *Alcaligenes faecalis* strain NCBI8687 is a redox protein (containing Mo, Fe, and S) catalyzing the transformation of arsenite [As(III)] to arsenate [As(V)]. In 2001, the investigation of the crystal structure of the protein revealed its heterodimeric organization. It is composed of a small subunit containing a Rieske [2Fe-2S] cluster and a large subunit harboring molybdopterin guanosine dinucleotide at the active site and a [3Fe-4S] cluster (4). The enzyme is involved either in arsenic detoxification in heterotrophic bacteria (9) or in energy generation in both chemoheterotrophic (15) and chemolithoautotrophic (10, 11) bacteria.

The genes encoding these two subunits were first identified and sequenced in the heterotrophic bacterium *Herminiimonas arsenicoxydans* strain ULPAs1 (9). Both genes were shown to be in the same operon. Given that the first gene of the operon encoded the Rieske subunit, it was named *aoxA*. The designation *aoxB* was used for the second gene encoding the large subunit. A Tat (*t*win-*a*rginine *t*ranslocation) signal peptide was identified at the N terminus of AoxA (9). Later homologues of these genes were identified in various organisms, and different nomenclatures were adopted: *aroB* or *asoB* and *aroA* or *asoA* for the small and the large subunit genes, respectively, in the chemolithoautotrophic arsenite oxidizer NT-26 (12) and in *A. faecalis* strain NCBI8687 (14). In the two last designations, "B" and "A" were used, respectively, to name the small and large subunits, in accordance with the nomenclature adopted by the biochemists, proposing that the molybdopterin subunit be called "a for alpha" and the small subunit "b for beta" (6).

In most arsenite-oxidizing bacteria, it has been shown that the synthesis of arsenite oxidase is regulated by arsenite. However, the regulation mechanism has only been studied in a few of them (2, 7, 8, 13). A complex mechanism for the expression of the structural genes for arsenite oxidase (*aoxAB*) involving quorum sensing as well as a two-component signal transduction system was described in *Agrobacterium tumefaciens* 5A (7). Two-component regulatory genes *aoxS* and *aoxR*, located directly upstream of *aoxAB*, were identified, respectively, as a putative sensor histidine kinase and as a putative transcriptional regulator. The AoxSR system was also described in the heterotrophic bacterium *Ochrobactrum tritici* SCII24 (2) and *H. arsenicoxydans* (8), as well as in the chemolithoautotroph NT-26 (13). In the latter, it was designated AroSR (13). The gene *aoxX*, encoding an oxyanion-binding protein involved in arsenite oxidation, has also been described (3).

It has become apparent that the use of various denominations is rather confusing, especially for the genome annotations, and each name is also in conflict with other nomenclatures. *aro* is used to define genes encoding proteins involved in aromatic compound synthesis, and *aox* is used to define aldehyde oxidase in bacteria as well as alternative oxidase in eukaryotes, while *aso* designates antisense oligonucleotides.

TABLE 1 Old and new nomenclatures of genes involved in arsenite oxidation

Protein	Gene designation by:		Reference
	New nomenclature	Previous nomenclature	
Arsenite oxidase			
Small subunit	*aioB*	*aoxA*	9
		aroB	12
		asoB	14
Large subunit	*aioA*	*aoxB*	9
		aroA	12
		asoA	14
Sensor histidine kinase	*aioS*	*aoxS*	7
		aroS	13
Transcriptional regulator	*aioR*	*aoxR*	7
		aroR	13
Oxyanion binding protein	*aioX*	*aoxX*	3

To bring some coherence to the designation of the genes involved in arsenite oxidation, we propose a new nomenclature (Table 1). All of the genes involved specifically in arsenite oxidation will be called *aio* (*a*rseni*t*e *o*xidase). The two genes encoding the small and the large subunits of the arsenite oxidase will be designated *aioB* and *aioA*, respectively, in accordance to the designation for the two subunits of the dimethyl sulfoxide (DMSO) reductase family of molybdenum-containing enzymes as described by Hille (6). However, associated genes encoding proteins such as cytochrome or nitroreductase, which can be found in various metabolisms, should not be included in this nomenclature system, but rather should be designated according to the genes to which they are homologous.

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It should be noted the AioBA enzyme is different from the anaerobic arsenite oxidase (ArxA), which was found in *Alkalilimnicola ehrlichii* (16).

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